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Improved Round Trip Efficiency for Regenerative Fuel Cell Systems

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6. AUTHOR(S)

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14. ABSTRACT

Refurbishment of the regenerative fuel cell test stand was completed including fabricating new plumbing, cleaning for oxygen service, and final assembly in the clean room. Initial operational testing in electrolysis and fuel cell modes was completed. Materials development for the hydrogen recovery reactor continued, and a bench-top test was devised and prepared. The preliminary and final designs of the hermetically-sealed scroll compressors were completed.

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Quarterly Progress Report

Project Title: Improved Round Trip Efficiency for Air Independent Regenerative Fuel Cell Systems

Project Period: June 18, 2010 to February 12, 2012
Date of Report: October 15, 2011

Recipient: Proton Energy Systems
Award Number: N00014-10-C-0369

Working Partners: W. L. Gore, AirSquared
Cost-Sharing Partners: None

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Project Objective:
The purpose of this phase of the effort is advance the understanding, implementation, and operational testing of the features that enable a regenerative fuel cell (RFC) to simultaneously be truly air independent and have high energy density. In addition, follow-on work is expected to investigate advanced membrane materials that enable higher efficiency electrolysis, substantially improving the practical energy density for RFC applications.

Objectives:
- Upgrade RFC system to enable full 4.4 kW fuel cell power output (previous system operated at 2 kW)
- Demonstrate improved closed loop capability through reduction of known mass losses: development of hydrogen recovery reactor and hermetically sealed compressors
- Perform durability testing on the existing RFC breadboard and refine startup and shutdown control systems

Background:
Navy underwater vehicle platforms (UUV, ASDS, SWCS, etc.) are demanding larger and larger energy storage capacities to accommodate longer underwater missions and increased platform power requirements. New energy storage devices with high volumetric energy density for underwater vehicles, both manned and unmanned, are therefore needed, such as regenerative fuel cell (RFC) systems based on proton exchange membrane (PEM) technology. An RFC consists of a fuel cell powerplant, an electrolysis system for recharging the reactants, and reactant storage. These water-

based energy storage systems have been shown to perform substantially better than traditional battery systems in areas such as rechargeability, specific energy density, and reliability. Advanced membrane and catalyst materials will enable higher efficiency electrolysis, substantially improving the practical energy density for regenerative fuel cell applications.

From a full proposal to develop an advanced demonstration system, Task 5 was selected for initial study. This task focused on membrane development and was reported on previously. The next step addressed operation of Proton's regenerative fuel cell system at the full 4.4 kW fuel cell design point and in a truly closed loop mode. The research objectives for Phase 2 of this task were broken into the following separate subtasks:

Task 2: Air-Independent RFC Component Durability Testing
Subtask 2.1: Re-commissioning of the existing RFC system
The contractor shall perform repairs and maintenance to the existing RFC system to achieve operability. Testing at relevant power density shall be initiated and baseline mass losses shall be measured.

Subtask 2.2: Upgrade fuel cell output capability
The contractor shall perform design work to determine requirements for doubling the fuel cell output capability. Upgraded components shall be installed and testing shall be performed at higher output power.

Task 3: Dissolved Hydrogen Recovery Reactor
The contractor shall design a hydrogen recovery reactor targeting 2,400 psi capability and build a prototype for integration into the RFC system. The contractor shall perform measurement of mass loss at up to 400 psi in order to compare to the baseline measurement.

Task 4: Hermetically Sealed Reactant Circulation Compressors
Improved scroll compressor prototypes shall be specified, procured and tested. The contractor shall integrate the new compressors into the RFC breadboard for testing.

Status:
Refurbishment of the regenerative fuel cell test stand was completed including fabricating new plumbing, cleaning for oxygen service, and final assembly in the clean room. Initial operational testing in electrolysis and fuel cell modes was completed. Materials development for the hydrogen recovery reactor continued, and a bench-top test was devised and prepared. The preliminary and final designs of the hermetically sealed scroll compressors were completed.

Task 2: Air-Independent RFC Component Durability Testing
Subtask 2.1: Re-commissioning of the existing RFC system
The new fuel cell stack has been received, but initial system checkout was conducted with the old fuel cell stack. The refurbished seals were received for the baseline scroll

compressors. All refurbished components were fabricated and sent out for oxygen cleaning as required. All components sent out for oxygen cleaning were received back in. System fabrication and re-assembly in the class 10,000 clean room was completed. Pump curves for the water circulation loop were verified, and the cleanliness of a sample of water from the assembled system was verified with a particle count. System was removed from the clean-room, positioned and installed in the test location. All sensors were calibrated. Nitrogen, hydrogen, and oxygen cycle purging of the appropriate sections of plumbing was completed to ensure purity of the internal gas volume. The PLC control software was cleaned up and updated to fix issues identified with previous testing and provide for more operator-friendly functionality. Initial testing with the electrolyzer was successful, including verification of the upgraded water filter. Initial testing with the fuel cell subsystem exhibited some voltage shut-downs. The root cause of the shut-downs may be related to the age/wear-and-tear on the old fuel cell stack. Diagnosis of the problem was underway at the time of this report, and the new fuel cell stack was being prepared for installation.

Subtask 2.2: Upgrade fuel cell output capability
Upgraded regulators have been installed and initial testing indicates that they are an improvement over the baseline. They have not been tested at full power yet, but indications are that a motorized control valve may need to be added to supplement the pressure regulation under dynamic conditions. The modified fuel cell heater / phase separator assembly was verified.

Task 3: Dissolved Hydrogen Recovery Reactor
The 2,400 psi capable pressure vessel was cleaned, verified and assembled in the clean-room. The water pressure drop through the vessel was characterized at several water flow rates. Initial screening of reactor media options and treatments as evaluated by water quality measurements was completed. Chemical modification of the reactor media was further characterized with SEM and EDS analysis. A bench-top, sub-scale operational test of the reactor operation was designed, and the test components were purchased and assembled.

Task 4: Hermetically Sealed Reactant Circulation Compressors
Subcontractor AirSquared completed a preliminary design that was reviewed by Proton. AirSquared then proceeded to a final design which was also reviewed by Proton. The final design output included a lengthy drawing package. In addition, Proton personnel made a site visit to AirSquared to meet the designer and key persons working on the development.

Task 1.0 Project Management and Reporting
Follow-up information to the June bimonthly phone call was submitted on July 1, 2011. The 4th quarterly report was prepared and submitted on July 15, 2011. A bimonthly call was held with ONR and Proton personnel on August 24, 2011. Follow-up information to the August bimonthly phone call was submitted on August 31, 2011. A visit was hosted and presentation given to incoming ONR program manager, Dan Dietz on September 26, 2011.

Plans for Next Quarter and Key Issues:
In the next quarter, measurements of system losses in electrolysis and fuel cell modes of operation will be taken in the current configuration. Bench-top, sub-scale characterization of the hydrogen recovery reactor media will be completed. Following those measurements, additional upgrades will begin with testing the fuel cell at higher output power and incorporating full scale hydrogen recovery reactor operation. Material procurement and fabrication of the hermetically sealed scroll compressors will be initiated. When the scroll compressor assembly is complete and delivered to Proton, incorporation into the breadboard system will begin.

Patents: None to date.

Publications / Presentations:
Status update presentations were given to the ONR team in July, August and September.

Task Schedule

Task Number	Project Milestones	Task Completion Date				Progress Notes
		Original Planned	Revised Planned	Actual	Percent Complete	
2	Complete test stand refurbishment	8/10/11		8/31/11	100%	Completed installation and start-up
2	Complete baseline testing of recommissioned unit	8/31/11		9/30/11	100%	Initial testing in fuel cell and electrolysis modes
3	Complete hydrogen recovery reactor testing	10/15/11	11/30/11		40%	Chemical treatment screening in progress
4	Procure hermetically sealed compressors	11/1/11	12/1/11		50%	Design completed
2	Complete upgrade fabrication/installation	11/30/11	12/10/11		20%	Pressure regulation tested
2	Initial multi-day full power testing	12/10/11			0%	Not yet started
1	Project Management				50%	

Budget Summary

Quarter	From	To	Estimated Billing	Actual Billing
2Q11	04/01/11	06/30/11		$219,352
3Q11	07/01/11	09/30/11		$285,617
4Q11	10/01/11	12/31/11	$290,469	
1Q12	01/01/12	03/31/12	$24,471	
		Totals=	**$314,940**	**$504,969**

Total Program: $819,909